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Focus on low carbon technologies: The positive solution

Abdeen Mustafa Omer

17 Juniper Court, Forest Road West, Nottingham NG7 4EU, UK

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Abstract

The use of renewable energy sources is a fundamental factor for a possible energy policy in the future. Taking into account the sustainable character of the majority of renewable energy technologies, they are able to preserve resources and to provide security, diversity of energy supply and services, virtually without environmental impact. This paper outlines possible energy savings and better performance achieved by different solar passive strategies (skylights, roof monitors and clerestory roof windows) and element arrangements across the roof in zones of cold to temperate climates. The aim of this work is to find possible design strategies, and to find solutions to provide thermal and luminous comfort in spaces of intermittent use and a poor aspect or orientation. In regions where heating is important during winter months, the use of top-light solar passive strategies for spaces without an equator-facing façade can efficiently reduce energy consumption for heating, lighting and ventilation. Passive solar systems for space heating and cooling, as well as passive cooling techniques when used in combination with conventional systems for heating, cooling, ventilation and lighting, can significantly contribute to the energy saving in the buildings sector, and the thermal behaviour of the dependent on the alternatives and interventions made on the building's shell. Exploitation of renewable energy in buildings and agricultural greenhouses can significantly contribute to energy saving. Promoting innovative renewable applications and reinforcing renewable energy market will contribute to preservation of the ecosystem by reducing emissions at local and global levels and will contribute to the amelioration of environmental conditions by replacing conventional resources with renewable sources that produce no air pollution or greenhouse gases and coexist comfortably with existing urban, agricultural and tourist land uses. As concerns society, development of the renewable market sector. Sustainable low-carbon energy scenarios for the new

E-mail address: abdeenomer2@yahoo.co.uk

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century emphasise the untapped potential of renewable resources. Energy efficiency brings health, productivity, safety, comfort and savings to homeowner, as well as local and global environmental benefits.

Keywords: Renewable applications; Development and enhancement; Built environment; Preservation of the ecosystem

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Nomenclature

A	heat transfer area, m^2
$A(s)$	temperature area over 25 °C, degree-hour
A_{max}	maximum temperature area, degree-hour
C_p	specific heat at constant pressure, kJ/kg K
F	shape factor, dimensionless
$F(t)$	temperature at time t truncated over 25 °C
G_b	beam solar radiation, W/m^2
G_d	diffuse solar radiation, W/m^2
G_T	total solar radiation ($G_b + G_d$), W/m^2
g	acceleration of gravity, m/s^2
h	heat transfer coefficient, $W/m^2 K$
$I(s)$	normalised temperature index for scenario S, dimensionless
k	thermal conductivity, W/m K
L	representative length, m
M	mass, kg
Nu	Nusselt number, dimensionless
Q	thermal gains, W
Ra	Rayleigh number, ($g\beta L^3 \Delta T/Lv$), dimensionless
R_b	beam radiation geometric projection factor, dimensionless
t	time, s
T	temperature, K
U	global heat transfer coefficient, $W/m^2 K$

Indices

c	convection
d	diffuse
i	internal, instantaneous
r	radiation
s	building materials
v	windowpane

Greek symbols

α	absorptance, dimensionless
ε	emittance, dimensionless
v	kinematic viscosity, m^2/s
ρ	reflectance, dimensionless
σ	Stefan–Boltzmann constant, $W/m^2 K^4$

1. Introduction

Spaces without northerly orientations have an impact on the energy behaviour of a building. For sustainable development, the adverse impacts of energy production and consumption can be mitigated either by reducing consumption, or by increasing the use of renewable or clean energy sources [1]. Bioclimatic design of buildings is one strategy for sustainable development, as it contributes to reducing energy consumption and therefore, ultimately, air pollution and greenhouse gas (GHG) emissions from conventional energy generation. Bioclimatic design involves the application of energy conservation techniques in building construction, and the use of renewable energy such as solar energy and the utilisation of clean fossil fuel technologies.

In the design or refurbishment of buildings to reduce energy consumption, the implementation of passive solar and day-lighting systems may not respond as expected since not all spaces might have a north-facing façade. Spaces without a northerly orientation impact on the energy behaviour of a building in three ways:

- they have reduced availability of daylight,
- heating in winter due to solar gain will also be reduced, and
- for temperate (mesothermal) climates in summer, solar gain will add to the cooling load.

For buildings with these attributes, to achieve the same energy performance as buildings that benefit from a good orientation and passive solar energy design, air-conditioning/heating is required, thus increasing the total power consumption. To improve the energy performance of a room without a north-facing façade, environmentally sensitive design strategies for lighting, ventilation, cooling or heating can be used depending on the location of the space. Zenithal openings horizontally or vertically glazed, light pipes, light shelves [2], tubular skylights [3] or sun ducts [4] can be used to meet lighting requirements. To improve the thermal performance, different strategies for indirectly gained solar heat, either through the ceiling or floor, are commonly used (e.g., roof ponds or rock beds). For ventilation, natural forces and passive systems such as solar chimneys can induce air movement or wind towers can have a major beneficial impact on ventilation [5].

Most systems are designed only for one purpose (e.g., lighting, heating or ventilation), and the overall energy performance can potentially be improved in combination with other systems [6]. For example, light pipes or light tubes can be combined with some passive heating strategies (e.g., sun spaces or thermal storage mass on roofs), or solar chimneys for natural ventilation and cooling in warm climates can be combined with day-lighting systems to reduce heat gains, thereby achieving better comfort levels. Skylight, roof monitors and clerestory roof windows represent a combination of thermal, day-lighting and natural ventilation systems, whereas operable windows are required for natural ventilation.

There are several types of spaces that may not possess a suitable northerly aspect or exposure, depending on the location, orientation or connection of that space to the exterior:

- Rooms facing south, east or west.
- In between spaces such as hallways, staircases and attics.
- Spaces where adjacent buildings obstruct north-facing windows.

- Spaces that have problems in lighting, heating, and cooling performance because of poor building design.

The present paper aims with energy using and energy saving technologies in farming, horticulture, livestock production, crop conservation, crop storage, underfloor heating, root zone warming, air knives, supplementary lighting, and energy efficient technologies available to farmers and growers. Examples include slurry treatment, dehumidification, horticultural lighting, and grain drying, environmental control for healthy livestock and heat recovery in combined heat, power and renewable energy sources. Monitoring projects on farms and nurseries, evaluate the costs and performance of new technologies. Computerised design programmes for calculating heating and ventilation requirements in livestock buildings, grain drying systems or lighting in horticultural units e.g., Venturi aeration of farm waste and disinfection of horticultural waste solutions. Typical applications: making parlour ventilation and fly control, calf pens, poultry houses, pig and sheep units, potato stores, greenhouses, and packing sheds.

2. Energy efficiency's major boost

Most business could make savings of up to 20% by introducing basic improvements in energy efficiency. Meeting the target of a 60% reduction in CO_2 emissions on environmental pollution is both technologically feasible and financially viable. Improved energy efficiency is a key to achieving that goal. A genuine investment of energy and resources to meet the environmental challenges the world at equity for a small planet.

The effects of GHG emissions are well known. Perhaps it is because of the stress placed on minimising the damaging effect of GHG that businesses look at their role in reducing emissions as a cost rather than as a source of potential long-term profit. One compelling reason why business should reduce emissions:

- It is right to reduce emissions and to use energy efficiently. There are inevitably concerned about costs. They want to provide goods and services at prices their customers can afford and without a competitive detriment.
- To reduce emissions in business is that customers care about the environment, and would give a choice, support environmentally conscious business.

Business has duties to shareholders and must be profitable in order to survive. The compelling reason for reducing emissions is one that is rarely addressed. Established well-built and proven technology and energy-saving measures must be implemented from environmental view-point, save 2260 kg of carbon dioxide (CO_2) each year or 3214 m^3 of gas [7].

2.1. Renewable energy

The energy conservation scenarios include rational use of energy policies in all economy sectors and use of combined heat and power systems, which are able to add to energy savings from the autonomous power plants. Electricity from renewable energy sources is

by definition the environmental green product. A renewable energy certificates system is an essential basis for all policy systems, independent of the renewable energy support scheme. It is important that all parties involved support the renewable certificate system in place. The potential of the most important forms of renewable energy such as solar and wind, biomass, and geothermal energies as shown in Tables 1 and 2.

The information technology in renewable energy brings with it a set of tools, expertise, in sight and support that may prove invaluable. Specially tools expertise and support in the areas of data and information quality, knowledge management, information dissemination, electronic publishing, networking, data acquisition, management, and control of complex systems, and group-ware. Effective application of these tools give even small and mid-size organisations the ability to manage their products, disseminate their ideas, discover knowledge they require, find project partners, manage projects, acquire data, process and manipulate that data, work on that data with colleagues around the world, lobby politicians, publish results and sell. The technologies required realising an information platform of the scope and nature. Development a technology platform would contain the necessary tools and building blocks with which such an ambitious information

Table 1
Energy sources for rural area

Source	Form
Solar energy	Solar thermal, solar PV
Biomass energy	Woody fuels, non-woody fuels
Wind energy	Mechanical types, electrical types
Mini and micro hydro	A mass water fall, current flow of water
Geothermal	Hot water

Table 2
Potential productive, end-uses of various energy sources and technologies

Energy source/technology	Productive end-uses and commercial activities
Solar	Lighting, water pumping, radio, TV, battery charging, refrigerators, cookers, dryers, cold stores for vegetables and fruits, water desalination, heaters, baking, etc.
Wind	Pumping water, grinding and provision for power for small industries
Hydro	Lighting, battery charging, food processing, irrigation, heating, cooling, cooking, etc.
Biomass	Sugar processing, food processing, water pumping, domestic use, power machinery, weaving, harvesting, sowing, etc.
Kerosene	Lighting, ignition fires, cooking, etc.
Dry cell batteries	Lighting, small appliances
Diesel	Water pumping, irrigation, lighting, food processing, electricity generation, battery charging, etc.
Animal and human power	Transport, land preparation for farming, food preparation (threshing)

management environment could be realised. Very specific requirements within which any such technology platform had to be developed were set right at project inception. These included:

- Modular, extensible architecture.
- Tools for rapid module construction.
- Uniform interface/functionality across modules.
- Full multimedia support.
- High interaction levels.
- Strong information ordering functions.
- Feature-rich application framework.
- Web-based, and fully searchable.
- Sensitivity to future technology trends.

A primary goal of the initiative was to realise, over time, a high level of acceptance and trust from the user community. Several attributes of any information system that could lead to such a level of acceptance were identified. These include:

- Global participation.
- Quality through peer review.
- Author-oriented system.
- Association with the society.
- Broad spectrum of services.
- Easy access to information.
- Good marketing.

For proper rural development the following must be considered:

- Analyse the key potentials and constraints on development of rural energy.
- Assess the socio-technical information needs for decision-makers and planners in rural development.
- Utilise number of techniques and models supporting planning rural energy.
- Design, import and interpret difference types of surveys to collect relevant information and analyse them to be an input to planners.

The unavailability and the acute shortages of the conventional energy supply (petroleum and electricity) to rural people forced them to use alternatives available energy sources like biomass. This situation caused serious environmental degradation beside the poor unsatisfactory services of some basic needs such as

- Food security.
- Water supply.
- Health care.
- Communication.

In order to raise rural living standards, the per capita energy availability must be increased, through better utilisation of the local available energy resources. It is necessary that a

vigorous programme for renewable energies should be set up (the challenge is to provide a framework enabling markets to evolve along a path that favours environmentally sustainable products and transactions). The use of renewable energy sources is a fundamental factor for a responsible energy policy in the future. Taking into account the sustainable character of the majority of renewable energy technologies, they are able to preserve resources and to provide security, diversity of energy supply and services, virtually without environmental impact. A reliable strategy has potential benefits for research and technology development:

- It contributes to the development of new solar applications, expanding their use and offering to enterprise ways to improve their competitiveness, productivity and their position in the market.
- It stimulates the renewable energy market by improving reliability, durability, efficiency, and competitiveness.
- Dissemination of the appropriate information will raise public awareness on environmental problems and at the save time will emphasise on the role of renewable energy technologies as a reliable, clean and environmentally friendly solution, thus enhancing its social acceptance.
- Will contribute to the improvement of the quality of the life by promoting an environmentally clean and innovative technology.
- Will, via collaboration among partners from different countries and regions, allow the establishment of continuing working relations, create new links, improve ways of communications and remove technical and non-technical barriers.

2.2. *Energy efficiency*

Efficient energy use has never been more crucial than it is today, particularly with the prospect of the imminent introduction of the climate change level (CCL). Establishing an energy use action plan is the essential foundation to the elimination of energy waste. A logical starting point is to carry out an energy audit that enables you to assess your energy use and determine what actions to take. The actions are best categorised by splitting measures into the following three general groups.

2.2.1. *High priority/low cost*

These are normally measures, which require minimal investment and can be implemented quickly.

- Good housekeeping, monitoring energy use and targeting waste-fuel practices.
- Adjusting controls to match requirements.
- Improved greenhouse space utilisation.
- Small capital item time switches, thermostats, etc.
- Carrying out minor maintenance and repairs.
- Staff education and training.
- Ensuring that energy is being purchased through the most suitable tariff or contract arrangements.

2.2.2. Medium priority/medium cost

Measures, which although involving little or no design, involve greater expenditure and can, take longer to implement.

- New or replacement controls.
- Greenhouse component alteration e.g., insulation, sealing glass joints, etc.
- Alternative equipment components e.g., energy efficient lamps in light fittings, etc.

2.2.3. Long term/high cost

These measures require detailed study and design e.g.,

- Replacing or upgrading of plant and equipment.
- Fundamental redesign of systems, e.g., CHP installations.

This process can often be a complex experience and therefore the most cost-effective approach is to employ an energy specialist to help.

2.3. Solar energy for building brighter

Solar energy technology using silicon cells to turn sunlight into electricity-photovoltaics (PV) has found many users since tiny cells first powered calculators. PV's potential for clean, renewable electricity generation is winning widespread acceptance. The three basic ways of using solar energy in domestic buildings are passive solar, active solar heating and solar PVs. Passive solar is a matter of good design and may be a small extra cost-maximising natural light and solar heating of fabric and space, while rejecting excess heat and avoiding glare. Active solar heating of water is a well-established technology, but it has been poorly taken. A typical domestic system on a roof can provide 50% of annual hot water demands, and give a payback time less than 10 years, while lasting much longer.

Solar electricity from PV cells has the biggest potential for worldwide impact. Long used for specialist applications such as remote transmitters, it is widely recognised as a solution to the problem of taking small quantities of power to the millions of homes and farms in developing countries in need of lighting, ratio, TV, telephones and light industries, as well as local clinics. The international agencies and many governments are investing heavily in this application. There is also a huge potential for using PV on buildings in the less sunny climes, such as western and northern Europe. PV generators are silent, clean in operation, highly reliable, less maintenance and extremely robust. Their expected lifetimes are of at least 20–30 years. They are also very modular and can be adopted to many locations or extended easily. Solar electricity can displace some fossil fuel use with consequent environmental benefits. The energy used during manufacture is quickly outweighed by the energy produced. When integrated into the fabric of a building, PV can displace other materials, saving some cost. They need no extra land and generate at the point of the use, thus reducing transmission losses, connected into the domestic electricity circuits, they displace purchased electricity and export the surplus to the network, evidenced only by the metre readings. PV is the renewable energy best suited to generation in the urban environment. The size of potential is summarised in Table 3.

The advantages of PV on buildings and the potential for solar energy eventually meet a significant proportion of electricity demands even in less sunny climates like the UK, has

Table 3
PV world

Country	Potential
Germany	Launched 100,000 roofs in 1999 (300 MW)
Switzerland	10 MW PV power installed by 2000
Dutch	The largest, at Amersfort, has 1 MW installed on roofs
Japan	Over 100 MW have been installed during 2000

driven several countries to provide a stimulus to their PV industries through subsidy programmes. The incentives for the interest of private owners are their environmental concerns, urging them to do their bit interest in technology, or simply wanting to be the first in the street. Incentive schemes can encourage rapid expansion of the market. The aim is to drive down prices to an economic level by expanding production, increasing industrial investment, bringing an improved technology, and establishing more effective supply chains. Awareness of the technology is increasing among developers and architects, and some of the non-technical barriers to growth are being addressed.

3. Low carbon building for the future

There was a growing awareness that cutting GHGs is a huge business opportunity. Business can both:

- Cut its energy costs and make itself more competitive, safeguarding profits, and employment.
- Grow by developing and adopting products based on the new low carbon technologies.

More than 170 countries have signed up to the Kyoto protocol. That is a huge potential market for products based on low-carbon technology. Pressure on business comes from governments, reflecting the concerns of votes, directly from consumers through green purchasing and indirectly through shareholder democracy. Non-governmental organisations (NGOs) have done a great deal to help create the market conditions that allows business to go down the low carbon route. Many governments are investing considerable sums in low carbon technology. There is a huge amount of research and development (R&D) going on, which could help to make a reality of Kyoto. The CO_2 emissions can be cut by around 60% over the next few decades, using existing and emerging technologies, which depends on:

- Active and positive engagement from the business world.
- Governments setting a firm policy context, so those innovative companies can profit.
- A strong input from NGOs who have also played a key role.

The business and the public sectors play their full part in delivering GHG reductions and prepare the ways for a low carbon economy up to 2050 and beyond. A truly low carbon economy is impossible without business involvement and support business development and carbon reduction go hand in hand. The vision and challenges are needed. Tackling carbon emissions is good business and introducing low carbon technology is good for the bottom line.

The Kyoto Protocol to the United Nations Framework Convention on Climate Change (UNFCCC) was initially designed to reduce GHG emissions from industrialised countries by 5%. There were many debates over the controversial area of restricting the buying, selling and banking of emissions reductions, particularly with regard to carbon sinks (the temporary storage of carbon in forests, soils, etc.). The potential for renewables is vast, uncontroversial, yet under-appreciated. In the case of solar PVs, for example even in a cloudy, rainy country like UK, modern PV technology applied to all available UK roofs would generate more electricity than the nation currently consumes in a year.

Global warming is in the process of teaching us that over security is best built by making sure our neighbours are secure as well. Its beachheads are becoming clear in proliferating climate extremes like the long-running drought. Unless we cut the burning of oil, gas and coal deeply the effects of global warming would ultimately be second only to nuclear war. A new global energy-security paradigm is urgently required. Budgets and policies should be consisted with the newly convergent imperatives of environmental and global security. New technologies were credited with offering low carbon solutions with fuel cells providing primary. Fuel cell technology has yet to prove itself and consideration should be given to the many innovative devices currently available that are grossly under-utilised. A need to face up to the rehabilitation of nuclear power despite any additional worries. Energy efficiency meaning improvements to the performance of power conversion and energy using devices would have a crucial role to play. The electricity supply industry talked, rather altruistically, of bringing power to the 1.6 billion people in the world that do not have access to it.

3.1. Low-energy device for integrated heating, cooling and humidity control in greenhouses

A combination of plant transpiration, wet soil, and warm temperatures leads to high humidity in greenhouse. High humidity promotes the spread of disease inside greenhouse. The growth of various types of fungi, such as downy mildew and grey mould, is greatly enhanced in a humid environment and these diseases can have a critical effect on crop quality and yield. The best way to control these fungal diseases is by humidity control. However, although ventilation is commonly used to control humidity during warm weather, the high cost of heating the inlet air during cold periods results in many greenhouse operations using fungicides rather than humidity control during cold weather. A cost effective, non-chemical method is required to replace fungicides for several reasons:

- There is growing consumer demand for pesticide-free products.
- Fungicide registrations are being cancelled.
- Botrytis cinerea and other fungi are developing resistance to fungicides.

Resistance to major groups of fungicides in botrytis has been documented in the United Kingdom, Italy, Canada and the USA. However, there are several important crops for which no fungicides effective against botrytis are registered. Thus, for several reasons, non-chemical methods of botrytis control must be exploited wherever possible. Humidity reduction is the most important, non-chemical method would offer a further advantage in controlling—calcium related disorders, which are humidity dependent and result in loss of both quality and yield.

The greenhouse effect is one result of the differing properties of heat radiation when it is generated by at different temperatures. The high temperature sun emits radiation of short wavelength, which can pass through the atmosphere and through glass. Inside the greenhouse or other building this heat is absorbed by objects, such as plants, which then re-radiate the heat. Because the objects inside the greenhouse are at a lower temperature than the sun the radiated heat is of longer wavelengths, which cannot penetrate glass. This re-radiated heat is therefore trapped and causes the temperature inside the greenhouse to rise. The atmosphere surrounding the earth also behaves as a large greenhouse around the world. Changes to the gases in the atmosphere, such as increased carbon dioxide content from the burning of fossil fuels, can act like a layer of glass and reduce the quantity of heat that the planet earth would otherwise radiate back into space. This particular greenhouse effect therefore contributes to global warming.

3.2. Bioclimatic approach

The question of thermal comfort is increasingly generating an intensive debate. The subject is not new but the exact solution is illusive to the fact that considerable part of the thermal sensation can only be evaluated by subjective means. Consequently the thermal comfort ranges do differ and seem to be complex functions of culture, physiology and geographical location. The human body is not exempt from the effects of the second law of thermodynamics. When the body heat cannot be dissipated to the surrounding environment; a condition that occurs when the ambient temperature is higher than the body temperature, then thermal discomfort starts. The three common body index temperatures are 36.6 °C (oral), 37 °C (anal), and 35 °C (skin temperature). While 37 °C is the temperature of the internal organs, the skin temperature is the reference datum for the thermal comfort sensation.

Buildings in the tropical area of the world are constantly exposed to solar radiation almost everyday. As a result, building design should aim at minimising heat gain indoors and maximising adequate thermal cooling so that user of these spaces can have adequate thermal comfort. To achieve this objective, buildings in this part of the world should have shapes and frames which should: (1) be responsive to this objective, (2) be properly oriented, and (3) the fabric of the buildings should be specified to prevent and have minimal use of active energy for economic viability. In order to meet the above requirements, it implies that buildings should be bioclimatic responsive. Observation of most buildings (both traditional and contemporary) in the built environment and also of building design approaches—past and present—reveals that most of the above criteria have not been strictly adhered to. Traditional buildings have laid too much emphasis on social-cultural and economic factors. Also, contemporary buildings, especially housing, have depended on imported building materials. Various problems have emanated from the present design approaches and philosophy. First, most buildings seem to be replicas of buildings in European countries in shape and form despite marten differences in climatic conditions. Secondly, despite observed climatic differences in various cities, forms and shapes of buildings tend to look alike. Thirdly, windows of buildings have not been properly oriented to maximise air movement for space cooling indoors. Window sizes and openings have not responded to physiological comfort. Finally, material specification for buildings in the housing sector has followed the same pattern despite the difference in climate. The tropical areas of the world are generally referred to as the overheated regions.

For building design purposes, overheated regions of the world are classified into three categories: (1) hot/warm, (2) arid/semi arid regions, and (3) temperate, both arid and humid regions. In order to properly access the effect of climate in any particular location and to determine appropriate climatic responsive design solution for buildings, it is necessary to evaluate the characteristics for the combined effect of thermal comfort parameters. These parameters should be carefully analysed for various areas. Two methods of climate analysis must be used so that a proper design solution for buildings can be made. The methods are: (1) the general atmospheric circulation model, and (2) the control potential technique. The general atmospheric circulation model (GACM) is based on the principle that the climate of a particular point in space and time is a result of three forces created by the earth's revolution, rotation and vertical heat transport. In other words, more characteristics of the climate of region will be considered. The vertical height is limited to the biosphere. The climatic data relevant to building design were then collected and analysed. The maximum and minimum monthly temperatures, the relative humidity both for morning and afternoon, solar radiation, and precipitation levels were collected from past records from meteorological stations.

It is suggested that the climate of a given location should be analysed in its own terms and that this analysis should directly lead to a certain architectural response type, i.e., of the appropriate control potential strategies. For a comfortable indoor environment to be achieved, the microclimate of the locality in which design is taking place should be carried out. The analysis of climate data closely related to the design environment will lead to more adequate and precise design decisions in terms of adequate orientation, spatial organisation, prevention of heat gain into spaces and better choice of building materials.

3.3. *Applications of solar energy*

These design strategies would provide the most effective combination for heating, natural ventilation and day lighting. Passive solar systems for space heating and cooling, as well as passive cooling techniques when used in combination with conventional systems for heating, cooling, ventilation and lighting, can significantly contribute to the energy saving in the buildings sector [8–12]. The available environmentally sensitive design strategies for

Table 4
Passive solar strategies for spaces without north-facing façade

Passive solar strategies/for	Natural illumination	Heating	Cooling	Ventilation
Skylight	×	×		×
Clerestory	×	×		×
Monitor	×	×		×
Saw tooth facing south	×			×
Light shelves	×			
Light pipe systems	×			
Thermal storage mess on roofs (roof pond)		×		
Thermosiphon (roof-floor)		×		
Roof greenhouse		×		
Black attic		×		
Wind tower			×	×
Solar chimney			×	×

improving the energy performance of spaces without appropriate orientation are shown in Table 4.

Design strategies that could be cost-effective and easily constructed, is the most important factor for the selection. As described by Baker et al. [13] a skylight is an opening located on a horizontal or tilted roof. It allows the zenithal entry of daylight increase the limit level of the lower space under the skylight. It can be opened to admit ventilation. In winter, a reflector can be used to enhance solar gain, since the amount of solar energy transmitted on a horizontal surface is considerably poor. In summer, exterior shading is required to avoid excessive solar gain [14].

The clerestory roof windows are vertical or tilted openings projecting up from the roof plane. They permit zenithal penetration of daylight, redirecting it towards the spaces below. They also allow natural ventilation. They are particularly effective for heating by direct sunlight entering a space and onto an interior thermal storage wall. Roof monitors raised section of roof with north and south openings. They permit the zenithal entry of daylight towards the lower zone increasing luminic level and allowing ventilation through the apertures. They have similar attributes to the clerestory in that sunlight is directed on to an internal thermal storage wall.

In this article considered the envelope area, shape and tilt of the glassed area and the arrangement of the elements across the roof area. Further studies are required to measure the influence of diffuse glazing in the distribution approaches. Different approaches could be appropriate for different situations and environmental conditions depending on heating, day-lighting, ventilation requirements, or construction facilities. The more important aspects to be considered are the glazing tilt and orientation of the element. The arrangement of the zenithal strategies has little influence in the thermal performance; however, regions with heavy snowfalls in winter will have an impact on the design strategy. Snow accumulation can cause problems for large elements in terms of roof structure and insulation, and smaller elements will be a structure and insulation, and smaller elements will be a better solution. In addition, these arrangements are more expensive and have more building, structural complications. The element and roof join is usually a weak point in the roof structure so that the use of many elements will cause problems with roof insulation water leakage. The roof monitors with their north- and south-facing openings allow a better quality of illuminance giving the whole spectrum of colour. It is also important to note that roof monitors had the best-combined results in terms of lighting and thermal effects. Coupled with the possibilities of ventilation by having the two openings (north and south windows) operable, this will also allow the removal of the exhaust air in summer.

4. Theoretical foundations

The analysis of thermal exchange among building components can be performed for any number of elements. However, the basic limitation to its calculation remains the choice of pertinent heat transfer coefficients. In this paper three basic elements are considered in a lumped-parameter approach: the building materials (structure and fittings, including finishing, of floor, walls, and roofs), a single window, and the inside air. The value of this last variable is taken to represent the pertinence of design.

A limiting condition to lumped parameter analyses is the definition of adducted heat transfer coefficients among the system, components, and among these and the environment. These coefficients are needed to solve the quasi-steady-state equations that

describe the heat balance in each of the relevant system components. In the absence of ventilation, the windowpane heat balance equation can be written as

$$M_{\mathrm{v}} C_{p_{\mathrm{v}}}\,\mathrm{d}T_{\mathrm{v}}/\mathrm{d}t = Q_{\mathrm{v}} A_{\mathrm{s}} U_{\mathrm{sv}}(T_{\mathrm{v}} - T_{\mathrm{s}}) - A_{\mathrm{v}} U_{\mathrm{vi}}(T_{\mathrm{v}} - T_{\mathrm{i}}) - A_{\mathrm{v}} U_{\mathrm{va}}(T_{\mathrm{v}} - T_{\mathrm{a}}). \tag{1}$$

In the preceding equation, the windowpane has an exposed area A_{v}, thermal mass M_{v}, specific heat $C_{p_{\mathrm{v}}}$ and its temperature T_{v} varies with time t as a result of solar heat Q_{v} received on its external face. T_{s}, T_{a} and T_{i} are, respectively, the building, ambient, and internal air temperature.

Solar gains Q_{v} are calculated by the following relationship:

$$Q_{\mathrm{v}} = A_{\mathrm{v}}(\alpha_{\mathrm{v}} G_{\mathrm{b}} R_{\mathrm{b}}(1 - \rho_{\mathrm{i}}) + G_{\mathrm{d}}(1 - \rho_{\mathrm{d}})\alpha_{\mathrm{v}}), \tag{2}$$

where the first inside the parenthesis describes direct solar gains, and the second, indirect or diffuse solar gains, as described in the nomenclature. Similarly, for the building materials,

$$M_{\mathrm{s}} C_{p_{\mathrm{s}}}\,\mathrm{d}T_{\mathrm{s}}/\mathrm{d}t = Q_{\mathrm{s}} - A_{\mathrm{v}} U_{\mathrm{sv}}(T_{\mathrm{s}} - T_{\mathrm{v}}) - A_{\mathrm{s}} U_{\mathrm{si}}(T_{\mathrm{i}} - T_{\mathrm{s}}) - A_{\mathrm{s}} U_{\mathrm{sa}}(T_{\mathrm{s}} - T_{\mathrm{a}}). \tag{3}$$

In the prior equation, the building inside temperature T_{s} is associated with a total thermal mass M_{s}, specific heat $C_{p_{\mathrm{s}}}$ and varies with time t as a result of solar heat Q_{s} received through the window. Total heat can be approximated by

$$Q_{\mathrm{s}} = A_{\mathrm{v}}(G_{\mathrm{b}} R_{\mathrm{b}}(1 - \alpha_{\mathrm{b}} - \rho_{\mathrm{i}}) + G_{\mathrm{d}}(1 - \alpha_{\mathrm{v}} - \rho_{\mathrm{d}}), \tag{4}$$

where, as in the preceding case, the first term inside the parenthesis describes direct solar gains, and the second, indirect or diffuse solar gains. And finally, for the air inside the enclosure, neglecting air exchange with the ambient,

$$M_{\mathrm{i}} C_{p_{\mathrm{i}}}\,\mathrm{d}T_{\mathrm{i}}/\mathrm{d}t = A_{\mathrm{s}} U_{\mathrm{si}}(T_{\mathrm{s}} - T_{\mathrm{i}}) - A_{\mathrm{v}} U_{\mathrm{vi}} - (T_{\mathrm{i}} - T_{\mathrm{v}}). \tag{5}$$

In this case, M_{i}, $C_{p_{\mathrm{i}}}$, and T_{i} refer to inside air mass, specific heat, and temperature, respectively.

The universally accepted nomenclature by Duffie and Beckman [15] is retained in Eqs. (1)–(5). Indices v, s, and i refer in all cases to, respectively, the windowpane, the building mass and the inside air, and the ambient. The equations are solved simultaneously by means of the variable, non-linear internal heat transfer coefficients U_{si}, U_{vi} and U_{sv}. Coefficient that refers to thermal exchange with the external environment, U_{va} and U_{sa}, are calculated according to Watmuff et al. [16]. In general, any U_{jk} value that depicts heat transfer between element j and element k can be approximated by

$$U_{jk} = h_{rjk} + h_{cjk}. \tag{6}$$

In Eq. (6), the term with sub-index r refers to radiation and the one with c, to convection. Both are very sensitive to temperature. The radiation term is usually approximated by Duffie and Beckman [15]:

$$h_{rjk} = \sigma\varepsilon\alpha F(T_j^2 + T_k^2)(T_j + T_k), \tag{7}$$

where σ stands for Stefan–Boltzmann constant, α is the thermal absorptance, ε is thermal emittance and F is the geometric shape factor, in such a way that radiative transfer per unit area is calculated as

$$q_{rjk} = h_{rjk}(T_j - T_k). \tag{8}$$

No generally acceptable coefficients are available for this application. However, it is possible to employ adapted expressions for heat transfer by natural convection in closed

cavities, such as can be found in Thomas [17], making use of the adequate aspect-ratio relationships. For the convection term,

$$h_{cjk} = N_u k/L\, CRa_L^m (H/L)^n. \tag{9}$$

In this case, the convective heat transfer coefficient is sensitive to the characteristic distance L, conductivity k of air at the mean temperature inside the envelope, Rayleigh number Ra, aspect-ratio H/L, constant C and powers m and n are adjusted to experimental results below.

For U_{vi} and U_{si}, $h_r = 0$, and h_c values are calculated with Eq. (9) using $C = 0.162$, $m = 0.29$, $n = 0$, $H/L = 1$ and $L = 1.2$ for U_{vi} and $L = 1.7$ for U_{si}.

Finally, the required temperature dependent air transport properties were evaluated by the following expression, which are valid between 2 and 77 °C with temperature expressed in k:

Thermal diffusivity, $\alpha = 1.534 \times 10^{-3}\,\mathrm{T} - 0.2386$ ($\times 10^{-4}\,\mathrm{m^2/s}$),
Kinematics viscosity, $v = 0.1016\,\mathrm{T} - 14.8$ ($\times 10^{-6}\,\mathrm{m^2/s}$),
Thermal conductivity, $k = 7.58 \times 10^{-5}\,\mathrm{T} + 3.5 \times 10^{-3}$ (W/m K), and
Thermal expansion coefficient, $\beta = \mathrm{T}^{-1}$ (K^{-1}).

In order to depict the relative contribution of each of these techniques to inside temperature, a dimensionless index is defined as follows. When interior temperature exceeds 25 °C, it will be considered as a temperature discomfort condition. This reference temperature is widely elements. Then the following expression:

$$F(t) = \max(T_t - 25.25). \tag{10}$$

I_s a time function of truncated temperature and it will be able to estimate the overall discomfort by means of the integration along the day for each different scenarios S:

$$A(S) = \int_S F(t)\,\mathrm{d}t. \tag{11}$$

Then, for each passive technique, let

$$A_{\max} = \max[A(S):\ \text{for all scenarios } S]. \tag{12}$$

Finally, the normalised temperature index (Figs. 1 and 2) for each scenario S is

$$I(S) = A(S)/A_{\max}. \tag{13}$$

Naturally, it would be preferred, for comfort reasons that this index would be small, preferably nil. It may be seen that the variable is directly related to temperature discomfort: the larger the value of the index, the farthest will inside conditions be from expected well-being. Also, the use of electricity operated air conditioning systems will be more expensive the higher this variable is. Hence, energy expenditure to offset discomfort will be higher when comparing two index values; the ratio of them is proportional to the expected energy savings. When the external shade blocks the windowpane completely, the excessive heat gains belong to the lowest values in the set, and the dimensionless index will be constant with orientation. For the climate conditions of the locality, it can be seen that a naked window can produce undesirable heat gains if the orientation is especially unfavourable, when the index can have an increase of up to 0.3 with respect to the totally shaded window.

The most favourable orientation, which is due north, results in diminished excessive solar gains through the windows. However, most buildings cannot be oriented at will.

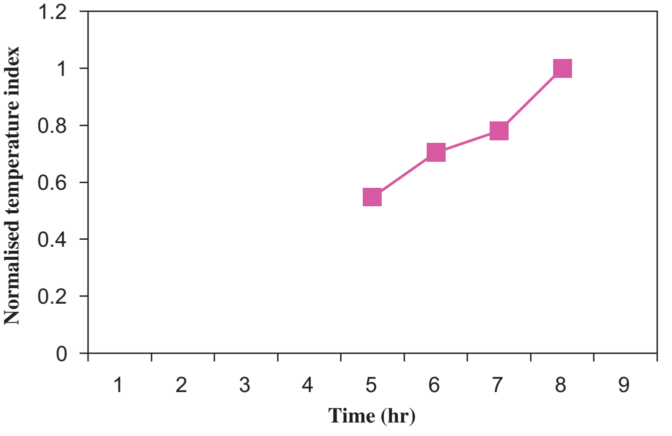

Fig. 1. Effect of roof extension on normalised inside temperature.

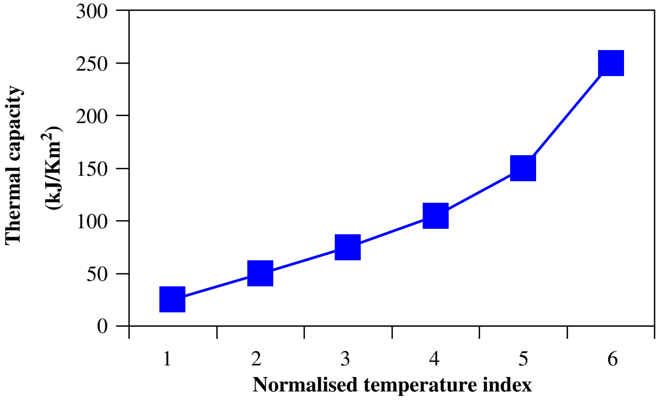

Fig. 2. Effect of thermal capacity on normalised inside temperature.

If the only possible orientation is due south, and no external shade is used, the index reveals extra heat gains of some 0.26 over the value of totally shaded window. Application of the model results from exploring the relative importance of the thermal inertia of walls, floor and ceiling. Heat stored in building materials, as proven in old, massive buildings, can be compensated during high insolation hours with thermal losses at night and early morning hours, when ambient temperatures are below 25 °C. Temperature variation will be lower for higher thermal capacities of building materials. However, it is known while thermal capacity increases the relative importance of individual heat flows change. For example, for lower wall temperatures, the contribution of radiative heat transfer will be reduced, and the relative importance of convective processes will increase, and thus the difficulty to calculate accurately the overall heat flows. The relevance of certain passive techniques is variable with prevailing weather. Where ambient temperature is mostly stable, thermal mass is no advantage, as Lee et al. [18] have shown for very light housing in

Korea. Vernacular architecture, where massive buildings are common, suggests the use of some passive techniques. These are provided with thick walls and small windows and when properly shaded and ventilated, can result in very acceptable temperature levels without the need of active systems in the extreme varying weather.

5. Heat pumps

Refrigeration is required for many applications ranging from cryogenic temperature controllers used in electric and biotechnology industries to the wide variety of general purpose food storage appliances used by consumers. Conventional refrigerators fall into two categories i.e., vapour compression systems or absorption refrigerators. The former uses mechanical pumps to actuate the compression and expansion of specific working fluids according to the principle of thermodynamics. The latter utilises heat energy (e.g., solar energy, waste heat, etc.) as a primary mover and a refrigerant/absorbent combination as the working fluid. The disadvantages of absorption refrigerators are that they are bulky and have a relatively low coefficient of performance [19]. Mechanically driven refrigerators have a high coefficient of performance and are very reliable in spite of their moving parts. However, they are noisy and can only achieve their potentially high coefficient of performance when the cooling power is large and the load is stable. Most importantly, the working fluids used in these refrigeration systems often escape into the atmosphere, where they are known to have harmful environmental [20]. Systems employing the thermoelectric Peltier effect are generally less efficient [21–23].

A direct result of the intensification of cattle, pig and poultry production over the last two decades is the high generation of aerial pollutants [24,25] consisting of particulates (e.g., organic dusts, micro-organisms) and gases such as ammonia, methane and nitrous oxide. Threshold limits for both human and animal can often exceeded in livestock buildings [26]. Reduction of these excessive pollutant levels by filtration has been shown to improve the health and performance of calves and pigs. Both incidence and severity of clinical and sub-clinical disease in calves were reduced and a 34.8% reduction in the use of antibiotics was recorded [27] pigs reached market weight up to 8 days earlier than those kept under standard conditions [28]. Reduction of pollutant levels would also help minimise the emission of harmful particulate and gaseous substances to the environment. It is well known that organic dusts and microorganisms can be carriers of disease while gaseous pollutants, such as ammonia, methane and nitrous oxide, can be toxic and/or cause odour nuisance. Despite the obvious need for pollution mitigation, there is a lack of techniques or devices, which are appropriate for application in the usually dusty and highly polluted atmosphere of animal houses. Existing methods such as filtration require frequent servicing and easy access, which may incur excessive cost and interfere with farmers' daily activities. A successful technique or device must be low-cost, easy to install non-intrusive, robust, have a minimal maintenance requirement and above all be effective. Here describe a novel mop fan with flexible fibre impeller for use in livestock buildings. The mop is irrigated with a continuous supply of water to the eye of the shaft via a narrow bore pipe. The fan is designed to remove particulate and gaseous pollutants from air, without resorting to filters, and may have potential for ventilating livestock buildings. The simplicity of the fan should allow its construction at low cost. The mop fan was developed by ICI [29] as part of a general activity involving rotating gas–liquid contractors. This fan is very similar to a conventional centrifugal fan except that it utilises a brush disk instead

of the blade disk of the latter. The simple construction makes it a robust fan with low unit cost, comparable with a conventional centrifugal fan. The brush, which is thinly coated with water to trap particles and to absorb gases, is made of corrosion resistant flexible fibre and is cleaned by a slow, and continuous supply of water to its surfaces.

The phase disengagement/gas scrubbing technique can be employed to remove dust from air before it is discharged to the atmosphere. Imposing a centrifugal acceleration field on a fine, and highly porous matrix [30] can carry this out. An alternative approach is to use a flexible fibre mop impeller mounted in a standard fan casing. The fan consists of a large number of strands of polymer filament, which may be irrigated with a scrubbing liquid such as water. The mop acts as an array of flails to propel the air. Dust is trapped on the mop surface by collision with the flails at high speed and is washed off by the water. The water/dust mixture (i.e., slurry) can be drained to the outside. The mop consisted of 864 fibres, each of 1 mm diameter, clamped radially on a shaft. This was mounted in a standard centrifugal fan casing. The fan was driven via a variable speed motor. Rectangular ducts of 117×155 mm were connected to the inlet and outlet of the fan. Water was supplied to the eye of the fan shaft via a narrow bore pipe and the flow rate of water was measured using a rotameter.

A model has been developed [31], which predicts the incidence, prevalence and severity of respiratory disease in pigs and clearly shows the benefits of reducing pollutant levels. Results show a 15.5% improvement in average daily weight gain, compared with vaccination, which gives only a 4.9% improvement. Particle removal was more effective for higher water injection rates, higher fan speeds and larger particles. At the typical fan speed of 700 rev/min and water injection rate of 2.5 ml/s, the particles removal efficiency ranged between 92% and 99% depending on the particle size. Further work is needed to improve fan efficiency and capacity by investigating effects of fibre number, fibre diameter and casing design. In addition, control of dust build-up in the fan casing should be incorporated into the mop fan design and the effectiveness of the fan in real animal buildings should be studied by means of field tests.

6. Reducing energy use

New technologies were credited with offering low carbon solutions with fuel cells proving primary. Fuel cell technology has yet to prove itself and consideration should be given to the many innovative devices currently available that are grossly under-utilised. Now more than ever, food and drink utilities are looking for ways to reduce energy costs. Refrigeration is the one of the main energy drains for food and drink sector. Food and drink processors should be looking to improve the efficiency of refrigeration systems to reduce the impact of the levy significant savings are possible. Cost savings of 10–20% are possible from zero- or low-cost measures. Savings of 30% or more can be achieved by investing in energy efficient refrigeration equipment. Observing several energy efficiency golden rules, applicable to all refrigeration systems, will significantly reduce energy consumption:

- Only use mechanical cooling for product that cannot be pre-cooled using fluids at ambient temperatures, to keep the load as low as possible.
- Size condensers and evaporators to maintain the lowest practical condensing and the higher effective evaporating temperatures.

- Eliminate or minimise head pressure control.
- Ensure that the compressor/refrigerant combination is the most efficient for the application.
- Insulate the suction line.
- Ensure the system contains the correct type and amount of refrigerant and that it is leak free.
- Keep condensers and evaporators clean.
- Defrost evaporators thoroughly whenever necessary (frost build-up impairs operating efficiency, increases running costs and could affect product quality, while a defrost-on-demand system can reduce power consumption by up to 30%.

The refrigeration category is divided into sub-technologies: evaporative condensers, liquid pressure amplification systems, automated air purging systems, some types of control systems, blinds, curtains, and covers for open retail cabinets, automated leak detection systems and some absorption cooling equipment. In the current climate of economic and environmental stringency an increasing number of institutes are looking to reduce the energy used by ancillary equipment, as a means of cutting costs and improving profits. Energy savings can be achieved with minimal energy management by covering:

- Background to the climate change.
- How to purchase energy more cheaply.
- Understanding where we use the energy and how to identify waste.
- Simple no- and low-cost opportunities.
- Grants and tax breaks for buying energy saving equipment.

7. Alternative approaches

7.1. Crop schedules

It may be possible to reduce energy consumption by reorganising the timing of crop production, i.e., planting later in the season. However, before adopting a strategy like this, the knock-on effects of marketing and prices should be thoroughly investigated.

7.2. Reduced temperature

Operating the greenhouse at a reduced temperature for part or all of the growing season can cut energy costs, but this is often at the expense of both crop yield and quality. This approach rarely offers a practical way to improve the energy efficiency of a greenhouse.

7.3. Plant spacing and shelving

Where it is feasible, plant densities can be increased. Crops can be grown on high level shelves or under benches-any of these configurations improve the use of greenhouse space and make for more efficient use of fuel.

7.4. Wind breaks

External wind speed has a greet effect on the heat loss from a greenhouse. Windbreaks can be a shelterbelt of trees or plastic mesh. Trees are cheaper than plastic mesh but obviously take longer to establish. Reducing wind speed by 30% can give a fuel saving of up to 10%. Windbreaks also go some way to protect greenhouse structures from damage during stormy weather.

8. Major redesigns

8.1. Combined heat and power

In the Netherlands, combined heat and power (CHP) installations are quite common in greenhouses, which grow high energy, input crops (e.g., salad vegetables, pot plants, etc.). Gas fuelled engines driving an electric generator are the most usual configuration. Heat from the engine oil, cooling system and exhaust is reclaimed and used to heat the greenhouse. CO_2 can also be recovered from the engine exhaust and used for atmosphere enrichment. Partnerships are drawn up between growers and power companies where heat and some electricity are supplied to the greenhouse. Any surplus generated electricity is exported off site into the national grid network. This approach is still in its comparative infancy here in the UK, but has become more popular over the last 2–3 years. It is therefore quite possible to engineer and design economically viable installations in the UK, but the economics of any proposal need close scrutiny. Any CHP scheme should be subject to an in depth feasibility study with particular attention being given to the use of the heat produced and the cost and retail price of the power being exported.

8.2. Boiler efficiency

This should be checked using a flue gas analysis kit. These kits consist of carbon dioxide (CO_2) gas analyser, a flue gas thermometer and a smoke tester. They are simple to use and with the information gained the burner can then be set up for optimum operation. The following table gives target value for CO_2 and Oxygen (O_2) as shown in Table 5. These targets are only a rough guide as individual boilers might have specialist requirements. Boiler efficiency is a key factor to eliminating energy waste as shown in Table 6.

Table 5
Target flue gas composition for boilers

Fuel	Theoretical CO_2% (dry basis)	Target CO_2% (dry basis)	Target O_2% (dry basis)
Bituminous coal	18.6	12.0	7.4
Dry steam coal	19.2	13.0	7.9
Coke	19.5	13.0	7.0
Natural gas	11.7	10.7	2.1
Propane	13.8	12.4	2.1
Butane	14.1	12.7	2.1
35 s fuel oil	15.4	12.7	3.8

Table 6
Energy saving technologies

Description of measures	Potential energy reduction (%)	Cost category
Monitoring and targeting	Up to 10	Low
Energy awareness training	Up to 10	Low
Efficient light sources	80	Low/medium
High efficiency motors	3	Medium
Variable speed drives	40	Medium
Improved controls	15	Medium
Thermal screens	35	High
New greenhouse designs	25	High
Flue gas condensers	15	High
De-centralised boiler plant	15	High
CHP	30	High
Thermal storage	20	High
Heat pump	30	High

Boilers that are used on low demands often operate at very low efficiencies. In this situation the fitting of automatic air inlet or flue dampers improves performance somewhat. As an alternative, consideration could be given to installing a smaller auxiliary boiler or electric flow boiler to heat restricted areas of the glasshouse instead of using the main boiler plant.

8.3. Insulation

8.3.1. Boiler and distribution pipes

The boiler, hot water tanks and distribution pipework should all be adequately lagged, kept weatherproof and in good repair. Wet lagging means virtually no insulation. Pipe runs are best above ground and visible-underground pipes make it difficult to inspect for leaks. Pipe insulation is important—a 1 m length of uninsulated 100 mm pipe carrying water at about 80 °C can waste 200 kWh of heating fuel a week.

8.3.2. Soil warming

Where hot water pipes or electric cables are used to heat ground level beds with 25–50 mm thick expanded or preferably extruded polystyrene sheet. This will minimise heat loss downward into the ground.

8.3.3. Oil storage

Where fuel oil is stored in pre-heated tanks these should also be adequately lagged and weatherproofed.

8.3.4. Greenhouse

The greenhouse itself presents the biggest opportunity to save energy (Fig. 3).

Rising hot air in the workplace means low temperatures at floor level, uncomfortable working conditions and high heating bills. The problem can be cured simply and effectively by the use of thermal engineering systems to return the hot air to where it is needed in the work area. This means that heater usage can be reduced, producing overall savings in

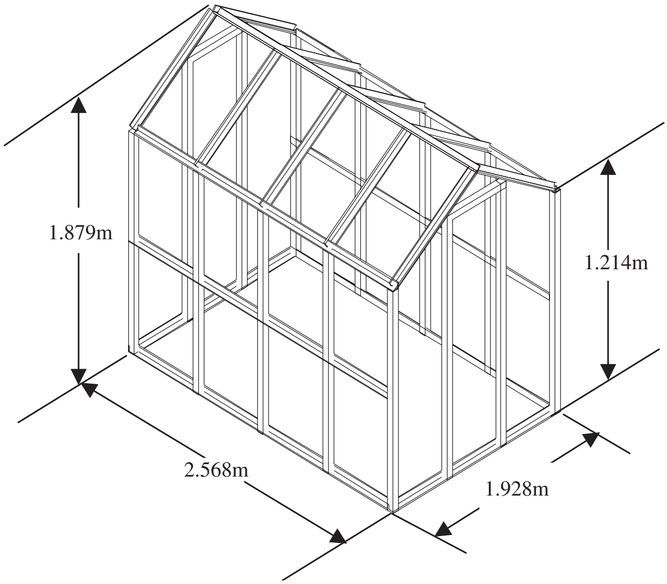

Fig. 3. Greenhouse and base with horticultural glass.

heating costs of as much as 30% [32]. The benefits of destratification can be obtained in any building where roof or ceiling is well above occupants and where an unobstructed downward flow of air can be achieved.

Modern greenhouse heating and ventilation systems are designed to maintain uniform temperatures. Within the heated areas however, temperature variations can and do occur, both vertically and horizontally. Such variations can result in sub-optional temperatures at plant level, plant diseases such as botrytis or, at the least, in uneven crop development. A typical temperature gradient, with thermal screens in use, can produce, at the roof apex, 3 °C above the set temperature-with fuel costs literally going through the roof.

The installation of thermal engineering systems strategically sited to create positive horizontal air circulation, as well as destratification, make a significant contribution to temperature uniformity. They offer the following benefits:

- Reduction in temperature gradient, fuel consumption and overall energy costs.
- Lower humidity within the plant canopy.
- Reduction in cold spots.
- Reduced condensation on leaf surface.
- Leaf temperatures much closer to air temperatures.
- Reduction in spore-borne diseases.
- Better CO_2 utilisation due to fewer dead air zones.

8.3.5. *Air leakage*

By reducing air leakage from the structure a 10–30% wintertime fuel saving can be made. Windy weather increases heat loss greatly, so attention to draught proofing and air leaks is very important. If the air change rate changes from say 0.5–5 changes per hour,

then the greenhouse heat loss can increase by as much as 45%. All openings to the greenhouse should be inspected to see that they make a good seal when closed and all cracked, broken or displaced glass should be replaced. Glass to glass joints should be sealed with clear silicone sealant. Such measures will reduce the number of air changes per hour dramatically and this will be reflected in savings in heating costs. Traffic in and out of the greenhouse should be minimised and personal instructed to keep access doors closed.

8.3.6. Thermal screens

Screens have been used in greenhouses for many years. Originally their use was restricted to blackout and shading for specific crop production. As energy saving measures became more important, retractable screens were developed as a means of improving energy efficiency for the same purpose. Depending upon the material used, screens can have a large impact on the ventilation, infrared radiation and convection. Manufacturers of thermal screens claim up to 60% energy savings—although 35% is more typical. Producers of high-energy greenhouse crops should seriously consider the economics of installing thermal screens. Simple polyethylene lining or bubble plastic is a cheaper but less effective alternative to a purpose-built retractable screen system. Incoming light loss may however cause problems with some crops.

9. Sustainable energy policy concepts

Improving access for rural and urban low-income areas in developing countries through energy efficiency and renewable energies. Sustainable energy is prerequisite for development. Energy-based living standards in developing countries, however, are clearly below standards in developed countries. Low levels of access to affordable and environmentally sound energy in both rural and urban low-income areas are therefore a predominant issue in developing countries. In recent years many programmes for development aid or technical assistance have been focusing on improving access to sustainable energy, many of them with impressive results.

Apart from success stories, however, experience also shows that positive appraisals of many projects evaporate after completion and vanishing of the implementation expert team. Altogether, the diffusion of sustainable technologies such as energy efficiency and renewable energies for cooking, heating, lighting, electrical appliances and building insulation in developing countries has been slow.

Energy efficiency and renewable energy programmes could be more sustainable and pilot studies more effective and pulse releasing if the entire policy and implementation process was considered and redesigned from the outset. New financing and implementation processes are needed which allow reallocating financial resources and thus enabling countries themselves to achieve a sustainable energy infrastructure. The links between the energy policy framework, financing and implementation of renewable energy and energy efficiency projects have to be strengthened, and capacity building efforts are required.

10. Climate change

The scientific consensus is clear-climate change is occurring. Existing renewable energy technologies could play a significant mitigating role, but the economic and political climate will have to change first. Climate change is real, it is happening now, and GHGs produced

by human activities are significantly contributing to it. The predicted global temperature changes of between 1.5 and 4.5 °C could lead to potentially catastrophic environmental impacts—including sea level rise, increased frequency of extreme weather events, floods, droughts, disease migration from various places and possible stalling of the Gulf stream. This is why scientists argue that climate change issues are not ones that politicians can afford to ignore. And policy makers tend to agree, but reaching international agreements on climate change policies is no trivial task [33].

Renewable energy is the term to describe a wide range of naturally occurring, replenishing energy sources. The use of renewable energy sources and the rational use of energy are the fundamental inputs for a responsible energy policy. The energy sector is encountering difficulties because increased production and consumption levels entail higher levels of pollution and eventually climate changes, with possibly disastrous consequences. Moreover, it is important to secure energy at acceptable cost to avoid negative impacts on economic growth. On the technological side, renewables have an obvious role to play. In general, there is no problem in terms of the technical potential of renewables to deliver energy and there are very good opportunities for renewable energy technologies to play an important role in reducing emissions of GHGs into the atmosphere—certainly far more than have been exploited so far [34]. But there are still technical issues to address to cope with the intermittency of some renewables, particularly wind and solar. However, the biggest problem with replying on renewables to deliver the necessary cuts in GHG emissions is more to do with politics and policy issues than with technical ones. The single most important step governments could take to promote and increase the use of renewables would be to improve access for renewables to the energy market. That access to the market would need to be under favourable conditions and possibly under favourable economic rates. One move that could help—or at least justify—better market access would be to acknowledge that there are environmental costs associated with other energy supply options, and that these costs are not currently internalised within the market price of electricity or fuels. It could make significant difference, particularly if, appropriate subsidies were applied to renewable energy in recognition of environmental benefits it offers. Cutting energy consumption through end-use efficiency is absolutely essential. And this suggests that issues of end-use consumption of energy will have to come onto the table in the foreseeable future.

11. Conclusions

Energy efficiency brings health, productivity, safety, comfort, and savings to home-owner, as well as local and global environmental benefits. The use of renewable energy resources could play an important role in this context, especially with regard to responsible and sustainable development. It represents an excellent opportunity to offer a higher standard of living to local people and will save local and regional resources. Implementation of greenhouses offers a chance for maintenance and repair services. It is expected that the pace of implementation will increase and the quality of work to improve in addition to building the capacity of the private and district staff in contracting procedures. The financial accountability is important and more transparent. Various passive techniques have been put in perspective, and energy saving passive strategies can be seen to reduce interior temperature and increase thermal comfort, reducing air conditioning loads. The scheme can also be employed to analyse the marginal contribution

of each specific passive measure working under realistic conditions in combination with the other housing elements. In regions where heating is important during winter months, the use of top-light solar passive strategies for spaces without an equator-facing façade can efficiently reduce energy consumption for heating, lighting and ventilation.

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